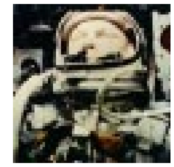
National Aeronautics and Space Administration

Glenn Research Center
Cleveland, Ohio

John Glenn Biomedical Engineering Consortium

Helping Astronauts, Healing People on Earth



The Structure of Human Health: Learning How Bones Rebuild

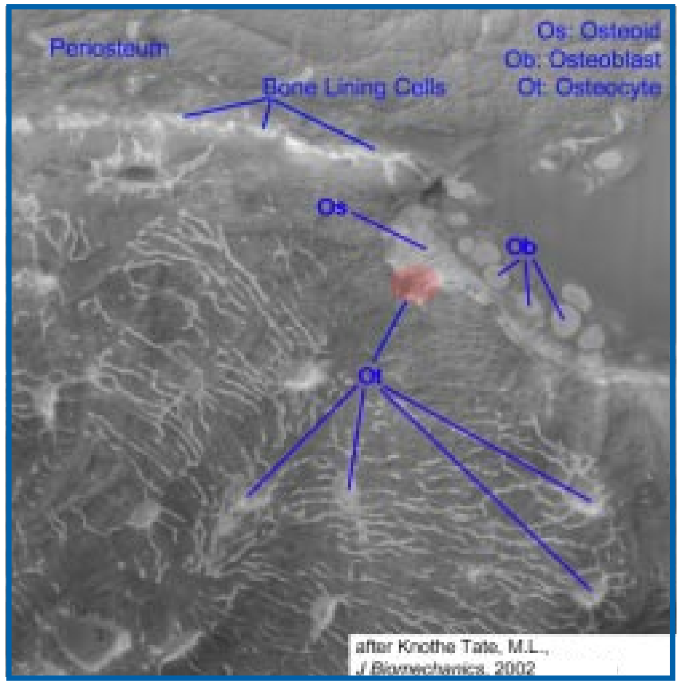
New microscopy techniques will be applied to bone cell cultures to determine how bone cell structure and activity changes in response to microgravity. This knowledge may be applied to patients on Earth suffering from osteoporosis.

One of the most serious side effects of the microgravity environment on human physiology is the acceleration of age-related osteoporosis. Astronauts lose between 0.5 and 2 percent of their bone mass per month while in microgravity, or 6 to 24 percent per year. By comparison, women with Type I (hormone-related) osteoporosis lose 3 to 4 percent per year, and the loss rate is even less in women and men with Type II (age-related) osteoporosis. Furthermore, the increased calcium excretion increases the risk of kidney stone formation.

Bone is a living tissue that is constantly being remodeled by osteoblasts, which build new bone, and osteoclasts, which resorb the bone matrix back into the blood stream. In a normal, healthy subject, these two competing processes maintain an equilibrium bone mineral density (BMD). Extra osteoblast activity in children allows for bone growth.

When gravitational loading (weight bearing) is removed, bones no longer sense the stresses and strains experienced on Earth, and the BMD decreases. Astronauts exercise to increase the loads on bones, and thus, stresses and strains. The processes that change the BMD in microgravity are still not well known; it is believed that microgravity inhibits bone formation, but that most of the bone loss comes from increased bone resorption.

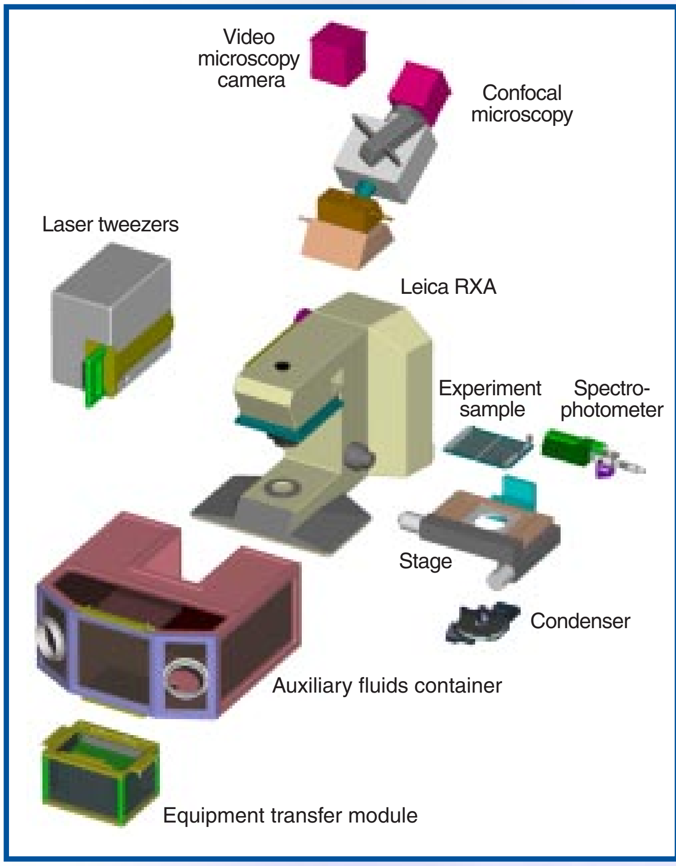
With support from the John Glenn Biomedical Engineering Consortium (GBEC), principal investigator Gregory Zimmerli of Glenn Research Center (GRC) and co-investigators David Fischer and DeVon Griffin (GRC) and Melissa Knothe Tate (Cleveland Clinic Foundation) are investigating the effects on bone cell cultures of countermeasures other than exercise.



Photomicrograph showing an area of remodeling on the surface of a bone that was immobilized, which may be comparable to bone loss in space. Courtesy M.L. Knothe Tate, CCF.

The effects of pharmacological agents on osteoclasts and lymphocyte activity will be tested. The effects of mechanical loading, hydrostatic pressure, and fluid flow through the cell culture may also be assessed. Finally, the effectiveness of acoustic vibrations and electromechanical stimuli in promoting growth in cell cultures will be examined.

One goal of this research is to investigate the structure and activity of osteoblast and osteoclast cell cultures on Earth and in a microgravity environment by developing and/or using selected microscopy techniques. For the Earth-based research, conventional confocal microscopy and two-photon microscopy for enhanced contrast and better depth penetration into samples will be used. Two-photon microscopy is a relatively new fluorescence microscopy technique that relies on the absorption of two infrared photons by a fluorophore, which then emits a single photon in the visible range at approximately half the incident wavelength.



Light Microscopy Module.

The Light Microscopy Module (LMM) is an automated microscope facility being developed by NASA GRC for fluid experiments on the International Space Station. Such a facility could be modified to study bone loss at a cellular level. The LMM will have phase contrast, differential interference contrast, and confocal imaging capabilities. Using the LMM with an appropriate cell culture stage, it may be possible to view and study changes in red blood cells and loss of lymphocyte activity in microgravity in real time.

To use the LMM to enable on-orbit imaging of bone cell cultures, new hardware must be developed. The consortium research will examine the detailed ways in which the LMM should be modified to enable the study of bone cells and other cell cultures. For example, hardware could be developed to study small (microliter) samples of blood taken from the astronauts, providing an on-orbit view of blood cell structure and white-blood cell activity.

Benefits on Earth

On Earth, osteoporosis affects 10 million persons in the United States alone, and an estimated $10 billion is spent annually treating osteoporosis-related fractures. Although the mechanisms may be different, there is an obvious appeal to the idea that osteoporosis on Earth is related to bone loss in a microgravity environment. A treatment that works for one may turn out to be effective for the other.

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